Fourth Annual Conference on
Carbon Capture & Sequestration

Developing Potential Paths Forward Based on the Knowledge, Science and Experience to Date

Geologic Sequestration

Impact of Flowing Formation Water on Residual CO_2 Saturations in Deep Aquifers

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ZERT: a comprehensive DOE project exploring geologic CO_2 sequestration.

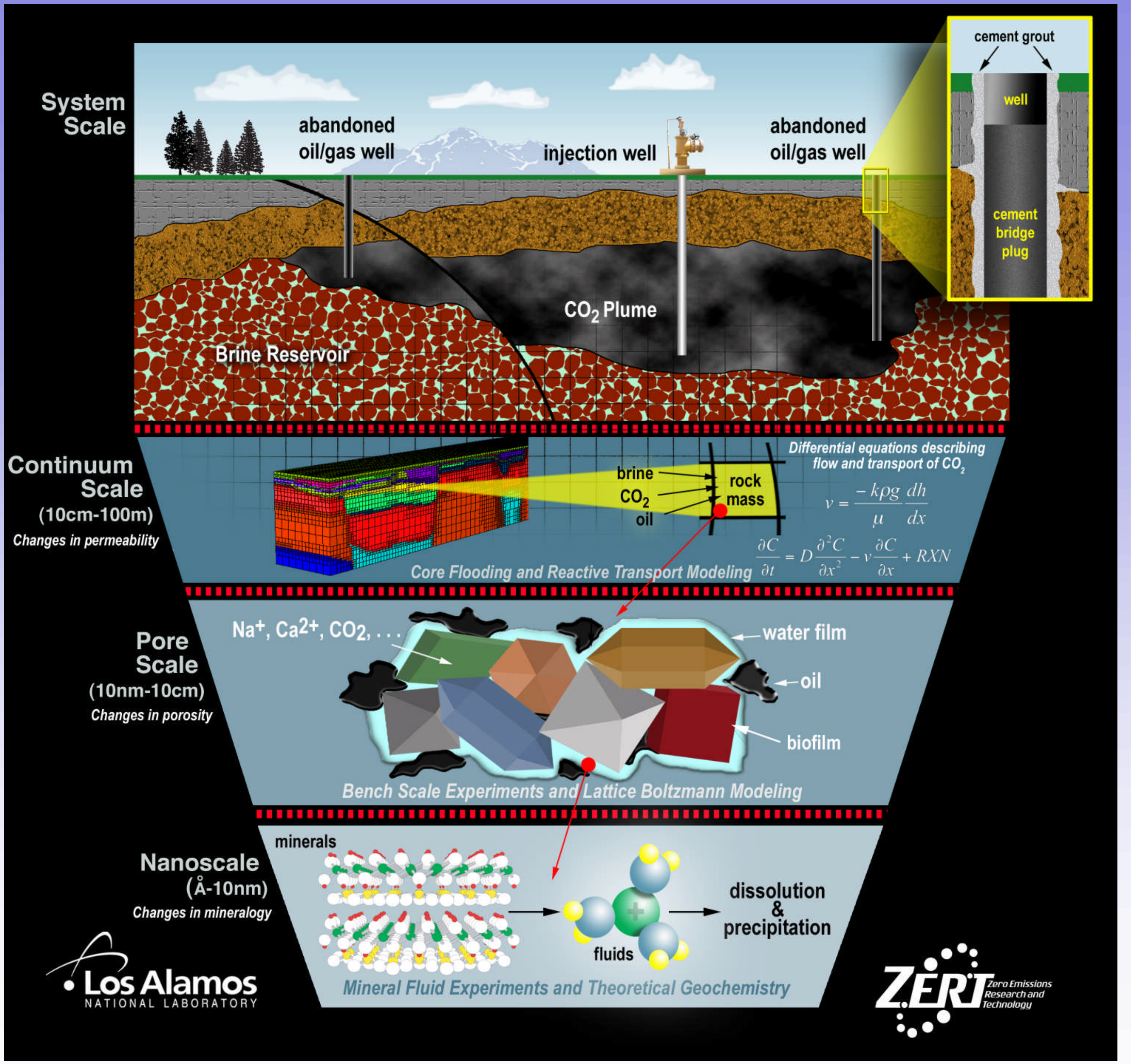
Zero Emissions Research and Technology

Los Alamos' contribution to ZERT integrates, from the pore scale to the site scale:

Field measurements
Laboratory experiments
Numerical modeling

Our simulations:

- Reservoir scale process model
- Incorporate into systems level calculations
- Characterize disposal site viability



Simulations use the Los Alamos Code FEHM

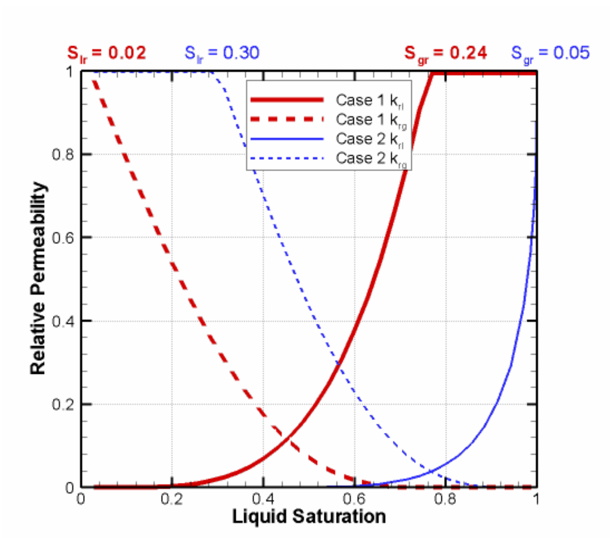
- Multiphase heat and mass transfer in porous and fractured rock
- Finite-volume approach = more accurate mass balances in complicated geometries
- Powerful grid generation capabilities
- Coupled flow, stress, and chemical reactions
- FEHM + GOLDSIM used for systems-level environmental decisions

Constitutive Equations

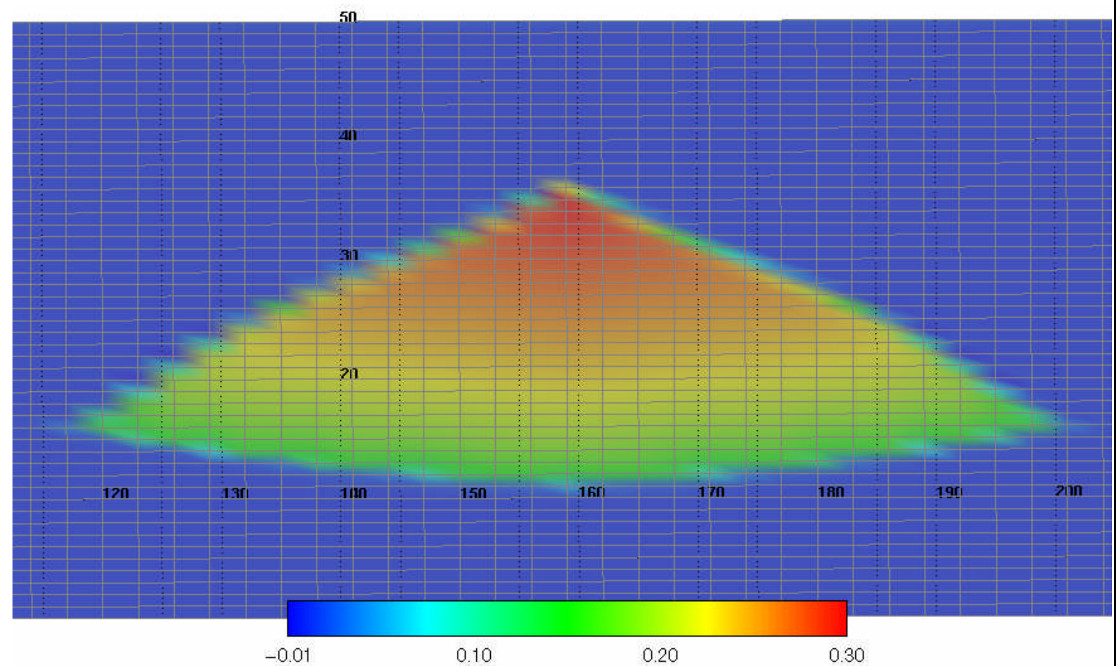
- Polynomial fits to NIST water-properties data
- Span and Wagner (1996) equation of state for CO_2
- Duan and Sun (2003) model for solubility as a function of P, T, and brine concentration
- Range of multiphase relative permeability curves
- LANL code-development experience permits rapid implementation of innovations

Code Validation

- Simulated injection and transport of supercritical CO_2
- Good match with PFLOTRAN (Peter Lichtner, LANL)
- Similar to TOUGH-2 results

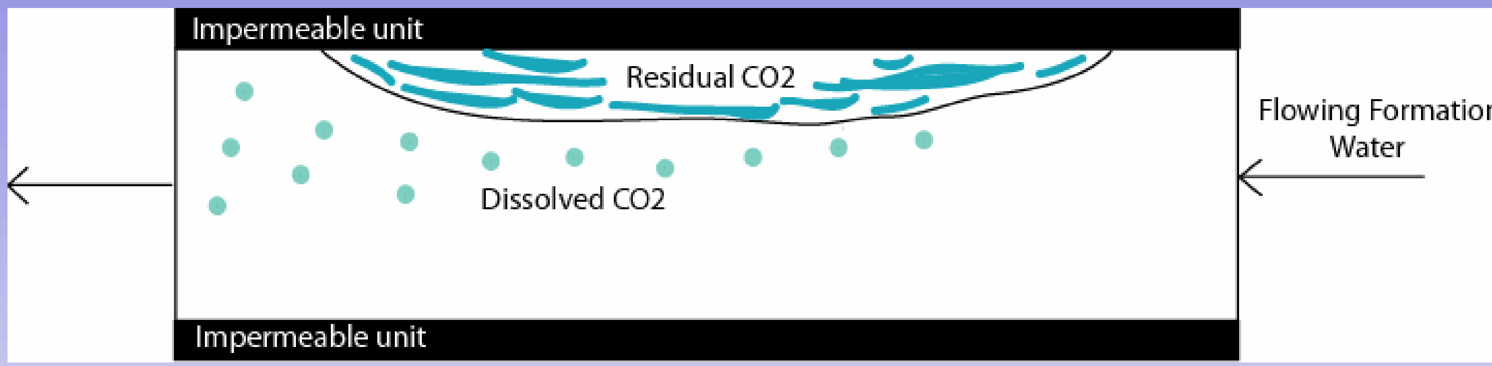


After Doughty and Pruess (2004)



Free CO_2 Saturation

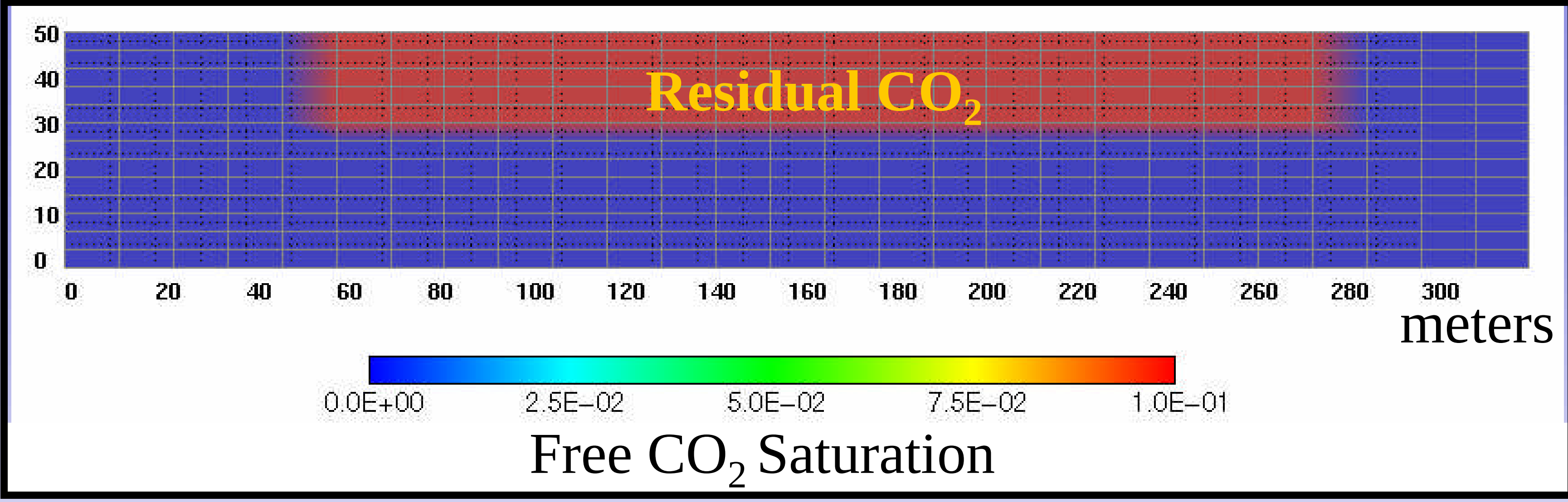
APPLICATION: Dissolution of Residual CO_2



Dissolution of residual CO_2 is affected by:

1) Rate at which formation water flows past
2) Dissolved CO_2 already in the formation water
3) Permeability structure of the reservoir
4) Diffusion coefficient of CO_2 in water

2-D Numerical Simulations of CO_2 Dissolution



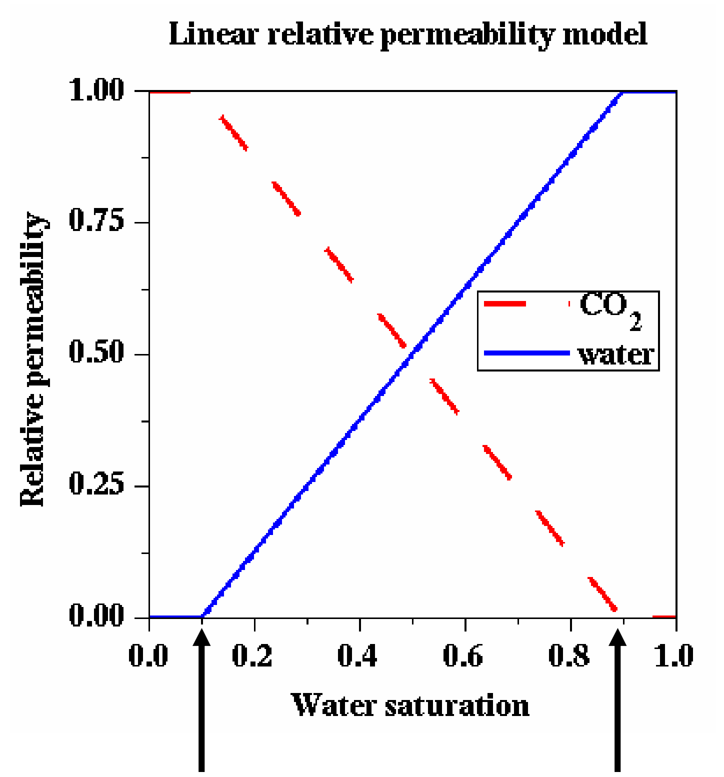
All simulations have:

- Same initial mass of residual CO_2
- Pressure = 20 MPa at the top of the domain (2 km)
- Temperature = 50 C
- Porosity = 0.15
- Dimensions = 321 m x 50 m

Base Case

Initial assumptions for variable parameters

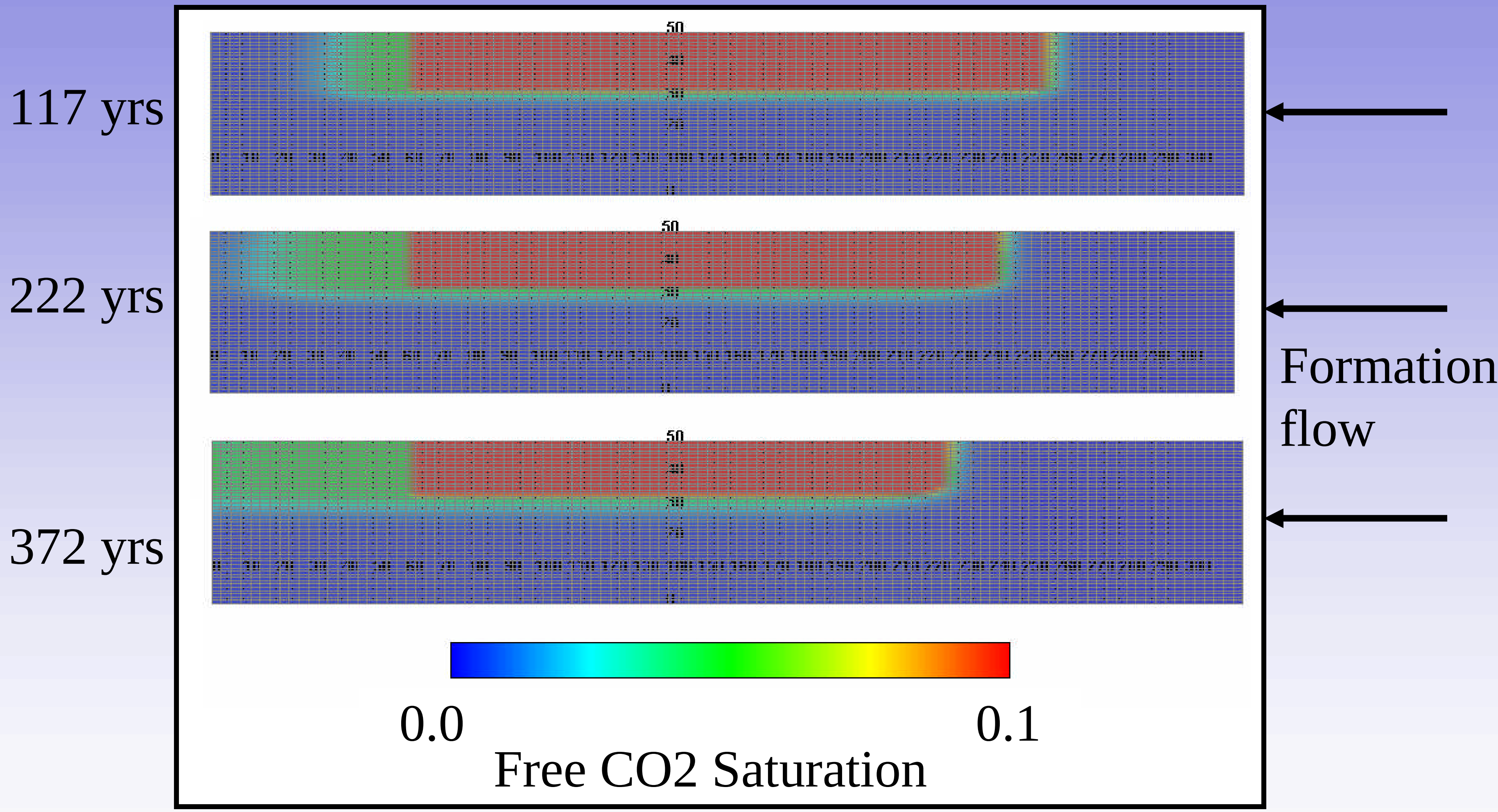
- 0.1285 m/yr formation volume flux
- Linear relative permeability $k_h = 10^{-10}\ m^2$, $k_v = 10^{-16}\ m^2$
- CO_2 porous medium diffusion coefficient = $1.x10^{-10}\ m^2/s$
- Formation water has no dissolved CO_2



Residual water saturation 0.1

Residual gas saturation 0.1

Time-Dependent Removal of Residual CO_2

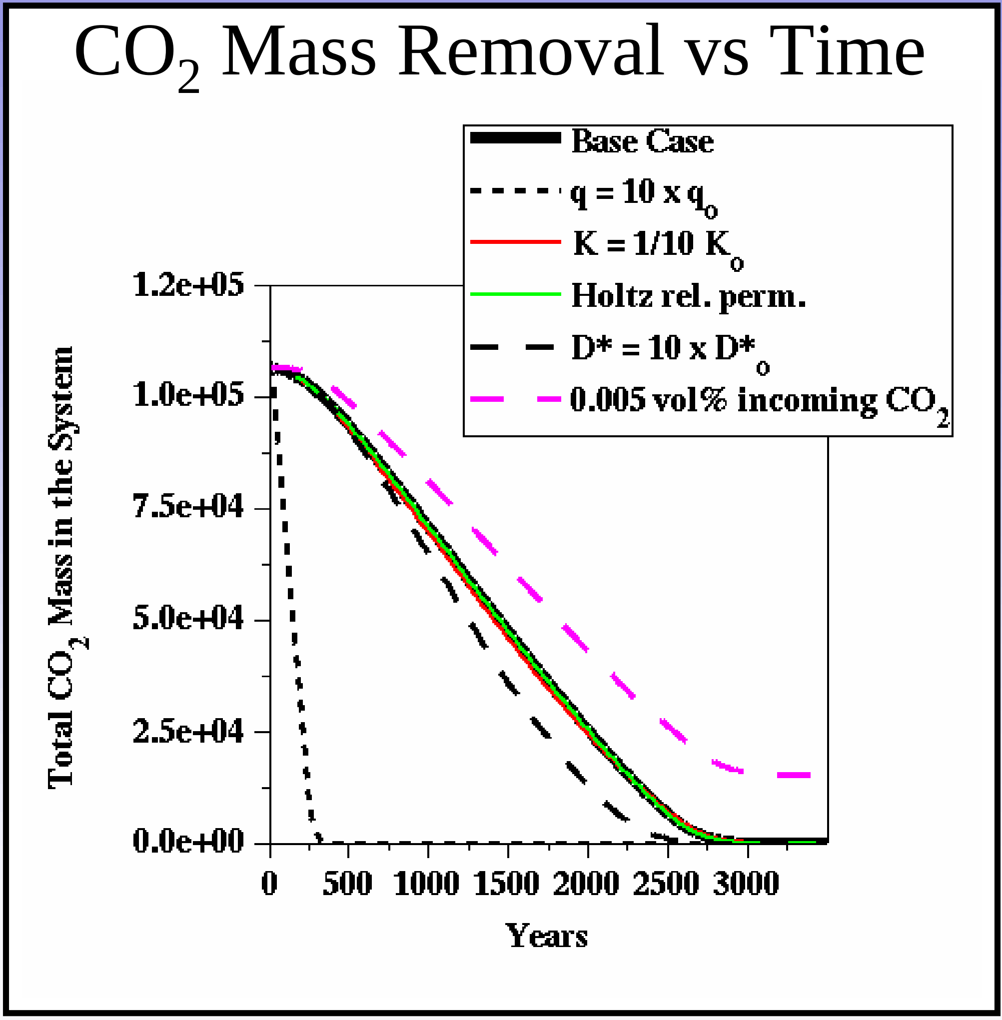


Sensitivity Results

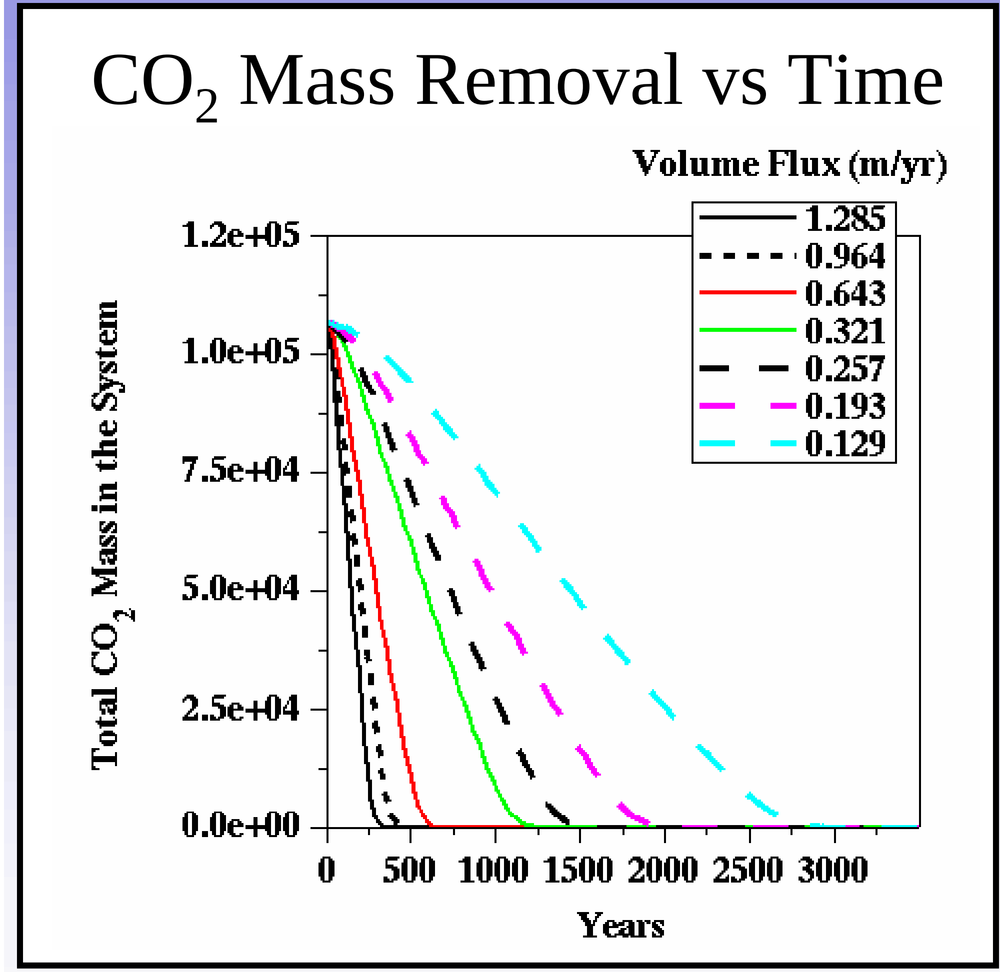
The most important parameters controlling dissolution are:

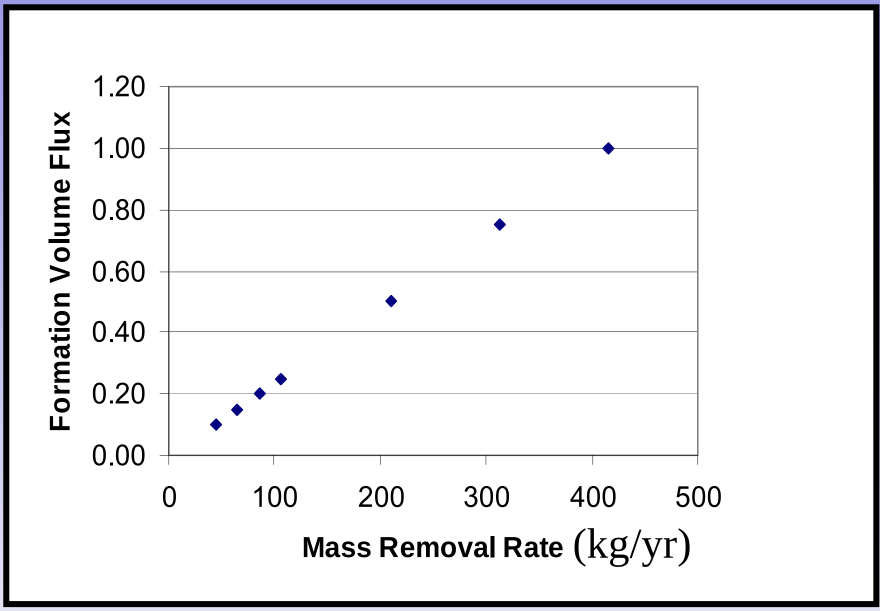
1) Formation volume flux

2) Dissolved CO_2 content of the formation water



Sensitivity to Formation Water Volume Flux

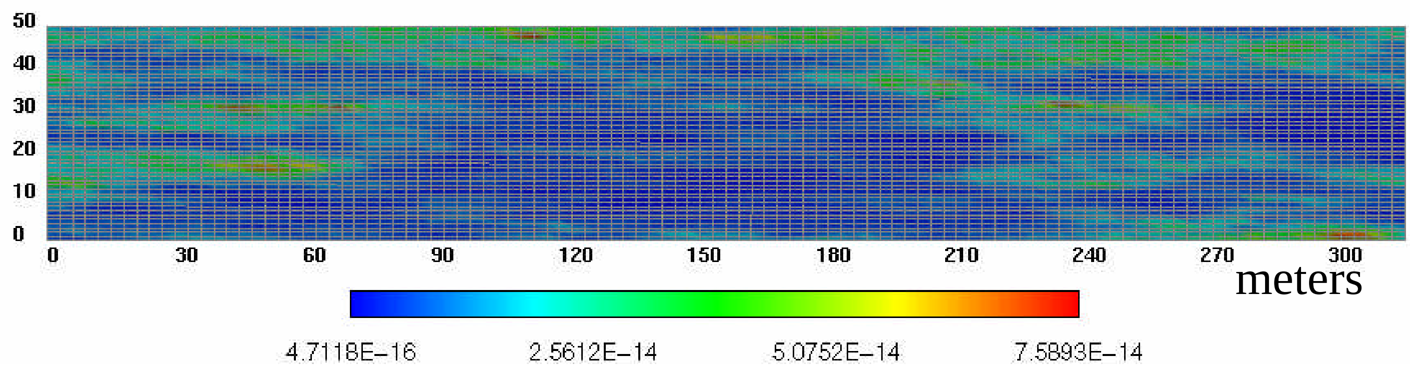




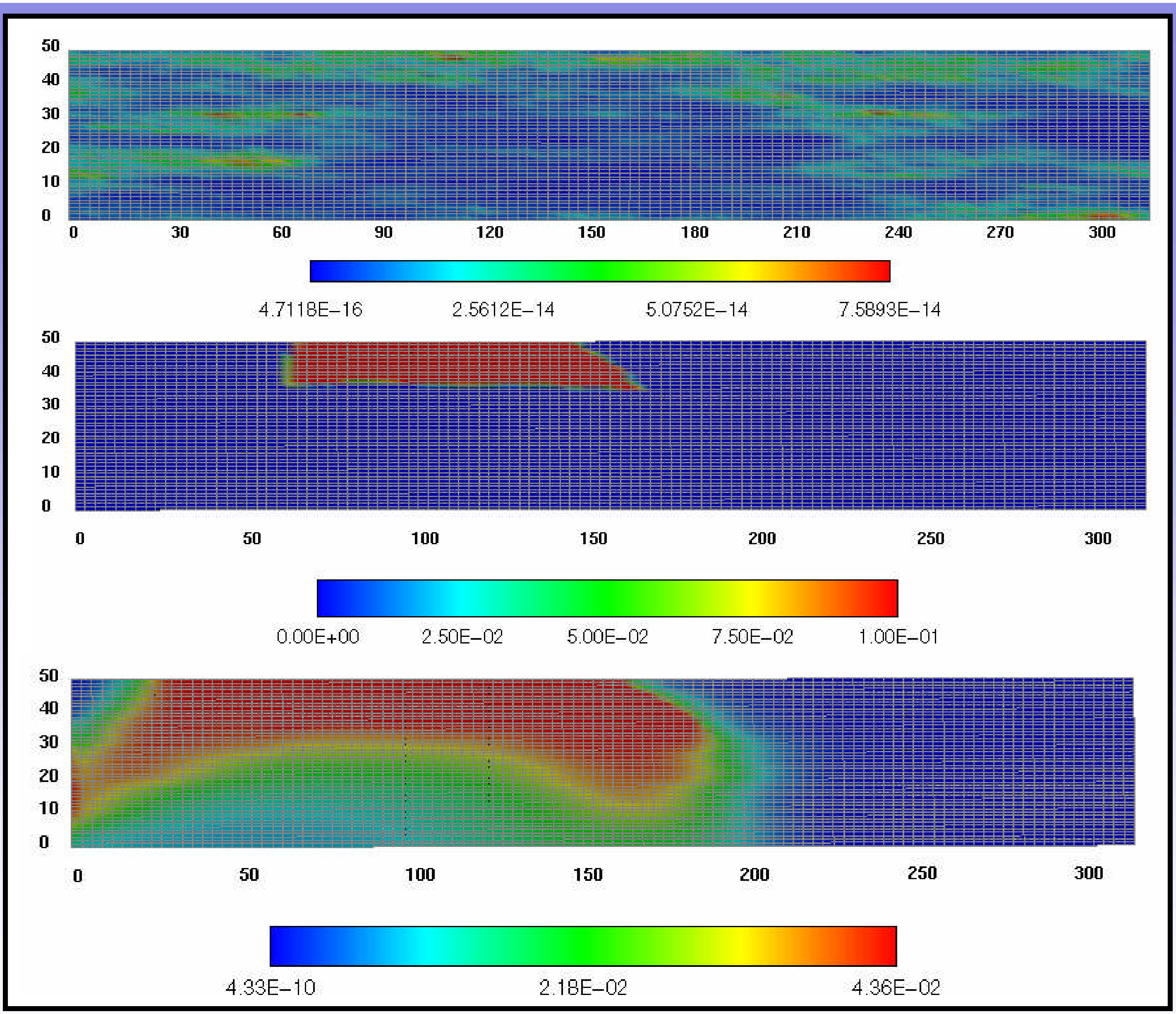
- Relationship between CO_2 removal rate and formation volume flux is nearly linear.

Example with Heterogeneous Permeability

- Correlated random field (Turning band method, Andy Tompson): $k_{h\ mean} = 1e\text{-}14\ m^2$



Horizontal permeability (m^2)



Horizontal permeability (m^2)

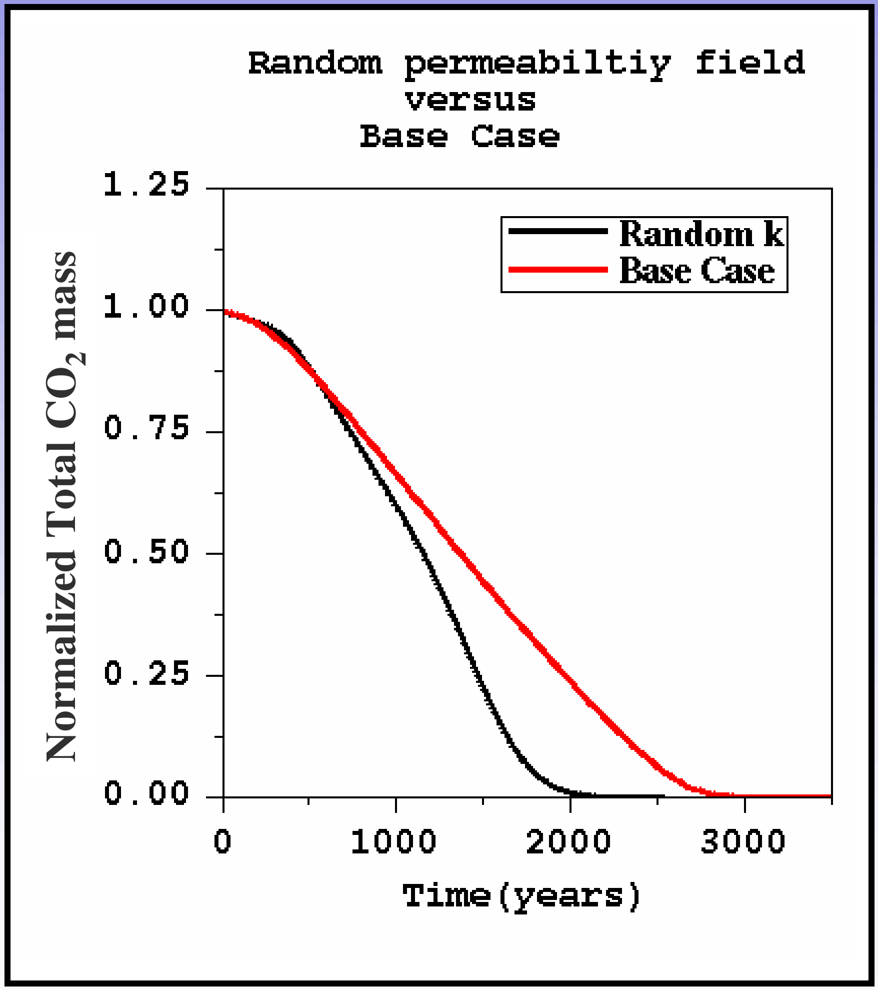
Free CO_2 Saturation

Volume fraction dissolved CO_2

Time = 745 years

CO_2 Removal Rate
Heterogeneous vs Homogeneous Permeability

- Focused flow in the heterogeneous case removes CO_2 mass more quickly



Conclusions

- Dissolution removes residual CO_2 slowly
  - Dissolution does not impact storage requirements over100-1000 years.
- For storage over 1000-10000+ years,
  - dissolution and transport of residual CO_2 may be important to site performance assessment.

Further Study

- Possible large increases in permeability may result when dissolution removes the residual CO_2 saturation
- Important for study of flow patterns through residual CO_2